Electric Vehicle (EV)-Grid Analysis Modeling

Project ID: van028 **PI: Bin Wang** Team: Wanshi Hong, Alan Jenn*, Cong Zhang
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*Lawrence Berkeley National Laboratory; *University of California, Davis,* **2022 DOE VTO Annual Merit Review**

Project Overview

Timeline
- Project start date: FY20
- Project end date: FY22
- Percent complete: 70%

Budget
- Total project funding: $750K
- Funding for FY 2022: $250K

Partners
- Lawrence Berkeley National Laboratory (LBNL)
- University of California, Davis

Barriers Addressed
- Methodology for evaluating the environmental sustainability and cost impact of mobility electrification/automation
- Relating component-level technologies to national-level benefits

Milestone FY-22

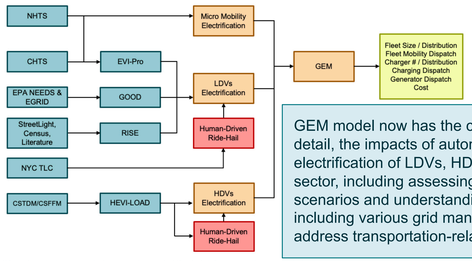
Milestones

Date	Milestone	Status
FY22 – Q1	Incorporate human-driven ride-hail operations in GEM based on best available data (e.g., NYC TLC, Chicago ride-share and Ride Austin)	Complete
FY22 – Q2	Finalize freight truck charging demand scenarios	Complete
FY22 – Q3	Finalize ride-hail, micro-mobility and CAV impact scenarios	On Schedule
FY22 – Q4	Complete integration of freight charging demand into GEM and generate results for net emissions impacts; Complete analysis of human-driven and fully automated ride-hail with GEM and produce standardized outputs for use by other Analysis project teams	On Schedule

Grid-Integrated Electric Mobility (GEM) Model

Approach

Objectives:
- Estimate the cost and benefits from integrated transportation & power systems from plug-in electric vehicles
  - Impact on grid operating cost
  - Impact on fleet and charging infrastructure requirements
- Accounts for charging profile and load flexibility within existing and emerging modes of transportation
  - Shared Automated Electric Vehicles (SAEVs)
  - Micro-mobility (e.g., Bikes and E-bikes)
  - Freight Trucks (e.g., Medium/Heavy Duty Vehicles)
- Minimize system costs across both transportation and power sectors

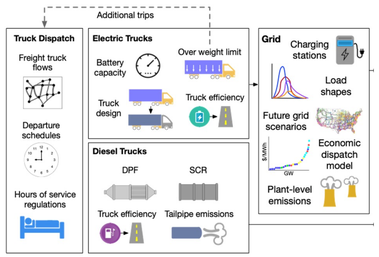


GEM model now has the capability to analyze, in detail, the impacts of automation technologies and electrification of LDVs, HDVs, and the micro-mobility sector, including assessing differing charging profile scenarios and understanding grid interactions, including various grid management strategies to address transportation-related load increases.

* CSTDM/CSFFM: California state travel demand model/freight forecasting model.

Grid-Integrated Electric Mobility (GEM) Model Extension

Truck electrification model



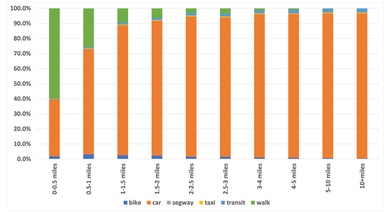
Using HEVI-LOAD tools, we have finalized the freight electrification and automation representation into GEM model accounting for infrastructure and fleet costs and demands constraints

Demand
- HDV travel demand
- Travel distance
- Charging demand

Fleet components
- Private owned heavy-duty electric vehicles
- Shared heavy-duty autonomous electric vehicles (SHAEVs)

Micro-mobility in GEM model

- Micro-mobility primarily serves short-distance trips (<10 miles)
- Modal shift opportunities for trips from cars to bike are significant.



- **Decision variables for e-bikes**
  - Energy charged/consumed
  - Bike Costs (fleet, infrastructure, maintenance, demand charge cost, ...)
  - Fleet size
  - Vehicle states (charging, moving, idle)
  - Demand allocated
  - Number of chargers

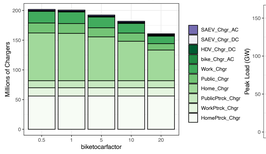
GEM Model Results

Micro-mobility study

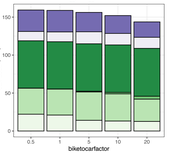
Accomplishments

Parametric Assumptions
- Car to e-bike mode shifts – biketocarfactor * [3.6%, 1.3%, 0.5%, 0.4%, 0.2%]
  In distance bins: 0-2 miles, 2-5 miles, 5-10 miles, 10-20 miles, 20+ miles
- biketocarfactor: 0.5, 1, 5, 10, 20
- 4 bikes per charger with 1KW charger level of up to 40 miles battery capacity

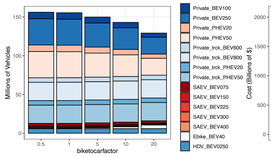
Total number of chargers needed



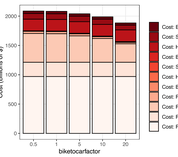
Peak charging load distribution



Fleet size for all vehicle components

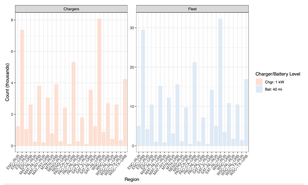


Total cost

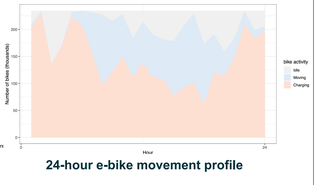


E-bike fleet size & charger distributions

X-axis is U.S. Grid Geographical Region by Urban/Rural
Y-axis is Number of Chargers and Total Fleet Size



24-hour e-bike movement profile



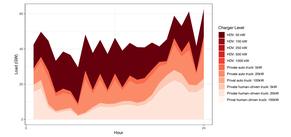
GEM Model Results

HDV fleet component study

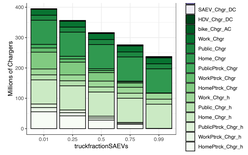
Accomplishments

Parametric Assumptions
- truckfracSAEV - proportion of shared automated trucks to meet total truck demand
- Penetration Rates S : 1%, 25%, 50%, 75%, 99%
- Freight components:
  - Shared heavy-duty autonomous electric vehicles (SHAEVs): S
  - Private owned heavy-duty electric vehicles: $P = 1 - S$
    - Human driven: $H = 50\% * P$
    - Automated: $A = 50\% * P$

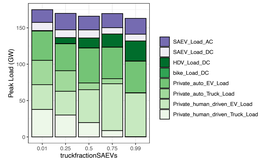
Nationwide 24 hour charging load profile



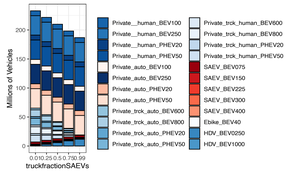
Total number of chargers needed



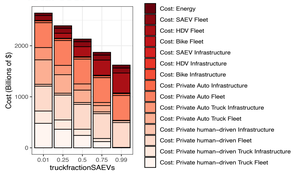
Peak charging load distribution



Fleet size for all vehicle components



Total cost



Major accomplishments

Accomplishments

- Publication progress:
  - Tong, Fan, et al. "Energy consumption and charging load profiles from long-haul truck electrification in the United States." *Environmental Research: Infrastructure and Sustainability*
  - Sheppard, Colin JR, et al. "Private versus shared, automated electric vehicles for US personal mobility: energy use, greenhouse gas emissions, grid integration, and cost impacts." *Environmental Science & Technology*
  - Tong, Fan, et al. "Health and climate impacts from long-haul truck electrification." *Environmental Science & Technology*
  - Another article has been drafted and will undergo an external peer review process
- Open access version of GEM:
  - GEM model with passenger mobility has been uploaded to GitHub
  - User tutorial with example setup and example dataset are provided

Summary & Future Work

- **Approach** – Outlined technical details of optimization and associated constraints of the system
- **Technical Accomplishments/Progress** – Finalized integration of long-haul truck electrification, human driven ride hail, micro-mobility, and grid modeling
- **Collaboration** – Partners with universities and other national labs
- **Relevance** – Extending VTO Benefits Analysis to include the upstream costs and benefits of EVs to the grid
- **Resources** -- Given our current resources we have been successful at accomplishing our goals to date
- **Future work** – Finalize ride hail and micro-mobility impact scenarios (*Any proposed future work is subject to change based on funding levels)*